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LIGHT ARMOR

Final Technical report

by

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I. **ABSTRACT:** Using former laboratory experience on examination the properties of silicate-polymer composite of low density and high protective ability against shaped charges armor specimens are designed and tested in range conditions within a wide scope of characterizing parameters. The results obtained are processed and analyzed. Conclusions and suggestions about the future work are made.

II. PRECEDING EXPERIENCE AND GENERAL INFORMATION

During the longstanding work in the field of armor protection the executive team achieved high and promising results some of which were introduced in modernization of tank T-55 armor protection as well as in several light armor vehicles [1, 2, 8, 9, 10, 11]. Some of the light armors introduced incorporated special high effective composites against shaped charges. The composites were developed for the purposes of the task and were based on natural and synthetic materials [4, 5, 6, 7]. The light armor developed satisfied to a significant extent the recent requirements and tendencies for a high effective armor protection against shaped charges combined with a low weight of the armor itself [12]. Modifications of the light armor were worked out for development of new armored objects and for modernization of existing ones.

That research was temporarily suspended. Later on the interest shown by USA Army experts made possible concluding the current Contract which enabled the executive team to continue working more systematically and purposefully with respect to some new specific requirements.

In compliance with the terms of the Contract the research is implemented and reported in four stages. First three stages are respectively reported in Interim Reports. The present Final Report gives render both of the forth stage of research and of the entire work done.

The activities upon the task "Light Armor" are characterized in the following substantial features:

1. The executive team considers the task fulfilled.

2. All intended activities are executed. Instead of 45 armor specimens 70 ones are manufactured and tested.

3. The financial discipline is strictly observed.

4. The executive team has received a valuable help with advises and opinions from the American experts which attended the tests.

III. BASIC INFORMATION ABOUT THE LIGHT ARMOR

The light armor consists of a metal or polymer box, sometimes with high strength steel ribs welded inside, and a silicate-polymer composite. The latter includes a matrix consisting of thermosetting resin and reactive filler and a phase including spheroid granules and metal filings or metal powders.

1. Matrix of silicate-polymer composite

1.1. Content

In general, the matrix includes:

- epoxy resin, in particular Bulgarian epoxy resin AP-1 with 15 to 20 epoxy groups;
- hardening agent diethylene triamine or polyethilene polyamine;
- surface-active agent, polyviol in particular;
- modifying agents - ethanol and water;
- foaming agents and reactive filler, in particular a natural material releasing nitrogen, consisting mainly of clinoptillolite and montmorillonite; and
- mineral dyes if necessary.

1.2. Preparation

Natural materials used as foaming agent and reactive filler need a preliminary preparation consisting in:

- grinding to particles of size under 100µm;
- heating to 520 °C for 3 hours;
- keeping on air for 48 hours in a low humidity room, and
- packaging.

After opening the package is kept on air for 2 to 3 hours.

During the heating the water included leaves the crystal which leads to forming acidic Lewis' and Brendstand's catalytic centers in the metal structure. Moreover, during the cooling the material selectively absorbs nitrogen from the air and after contacting with water the nitrogen is released which foams the system.

2. Phase of silicate-polymer composite

The phase may include spheroid granules of different composition, tablets of ferrous silicate, metal powders or metal filings.

1.2. Spheroid granules

The diameter of spheroid granules is from 4 to 30mm.

2.1.1. Composition

The granules consist mainly of oxides and silicates, i.e. I-20-20 and various metal powders may be included. The following mixes are prepared (in weight percentage):

- Mix 1: I-20-20 (Specimens No 15 to 22, 25, 26, 35 to 41);
- Mix 2: 88% I-20-20 and 12% tungsten powder (Specimens No 23 and 24);
- Mix 3: 88% I-20-20 and 12% copper compounds powder (Specimens No 28, 32, 46 and 47);
- Mix 4: 88% I-20-20 and 12% copper powder (Specimens No 29, 33, 50 and 51);
- Mix 5: 88% I-20-20 and zinc powder (Specimens No 30, 34, 42 and 43);
- Mix 6: 50% I-20-20 and 50% zinc powder (Specimens No 44 and 45);
- Mix 7: 50% I-20-20 and 50% copper compounds powder (Specimens No 48 and 49);
- Mix 8: 50% I-20-20 and 50% copper powder (Specimens No 52 and 53);
- Mix 9: Sixty volume percent of the granules are made of Mix 1; 31% are made of Mix 5; 3% are made of Mix 3; 3% are made of Mix 4; 1.5% are made of Mix 6 and 1.5% are made of Mix 7 (Specimens No 58 to 85)

2.1.2. Preparation

The spheroid granules are prepared according to [3]. After a consecutive mixing and homogenizing the mix "ripens" at 100 °C. Then the hardened material subsequently is ground and expanded in Portland cement at 100 to 900 °C.

- Spheroid granules of I-20-20 and zinc powder: During mixing and homogenizing of the mentioned components zinc powder is added which contains 98% zinc, 0.2% chlorine and the rest elements under 0.005%. Two types of granules are prepared: Mix 5 with weight percentage ratio between I-20-20 and zinc powder 88:12 and Mix 6 with ratio 50:50;
- Spheroid granules of I-20-20 and tungsten powder: During mixing and homogenizing of the mentioned components tungsten powder is added which contains

99.9% tungsten. The weight percentage ratio between I-20-20 and tungsten powder is 88:12;

- Spheroid granules of I-20-20 and copper powder: During mixing and homogenizing of the mentioned components copper powder is added which contains 99.9% copper with grain size 200 to 400 μm. Two types of granules are prepared: Mix 4 with weight percentage ratio between I-20-20 and copper powder 88:12 and Mix 8 with ratio 50:50;
- Spheroid granules of I-20-20 and copper compounds powder: During mixing and homogenizing of the mentioned components copper compounds powder, mainly copper sulfide is added which contains 20-22% copper, 30-35% sulfur, 30-33% iron, 8-12% silica and 2-3% alumina. The grain size is 80-100 μm. Two types of granules are prepared: Mix 3 with weight percentage ratio between I-20-20 and copper compound powder 88:12 and Mix 7 with ratio 50:50.

2.2. Tablets

2.2.1. Composition

Different types of tablets of non-homogenous composition are worked out which contain sodium and/or potassium metasilicate, oxides and silicates. The tablets are synthetic and are pressed and baked at a high temperature.

2.2.2. Preparation

Phaelite and calcium compounds are homogenized, moistened with 20% phosphoric acid and pressured under 5 kg/cm^2. Then part of the tablets are coated with glass frit containing mainly lead, chrome and copper and then are dried at 150°C and baked at 950°C. Four types of tablets are worked out for the purposes of the research task:

- Tablets Ch7: Pure phaelite is moistened with 20 % phosphoric acid and pressured under 20kg/cm^2. After drying the tablets are glazed one-sidedly with low-melting glass frit and baked at 950°C;
- Tablets Ch10: The composition and the preparation are the same. Both sides are glazed.
- Tablets Ch11: The composition and the preparation are the same. The pressure is 10kg/cm^2. Without glazing;
- Tablets Ch12: The composition and the preparation are the same. The glazing is made with low-melting glass frit containing more copper;
- Mix 10 consists of equal quantities of the mentioned types of tablets.

2.3. Metal filings

The filings are up to 3mm in length.

Some specimens contain copper compounds filings, e.g. bronze filings as filler in the phase. Specimens No 15, 16, 19 and 20 for testing on June 29, 2000 contained bronze filings with 3-4% lead. In all other specimens bronze filings free of lead are used.

2.4. Metal powders

Some specimens contain zinc powder in the phase of silicate-polymer composite.

3. Metal boxes

The light armor nature and the principle of interference between the armor and the jet suppose a light packaging. That is the reason why the most specimens regardless of dimensions consist of boxes of common purposed carbon steel of thickness 0.8, 1 and 2mm which aims clarifying the protective effect of the composite itself.

Some embodiments include plates of high strength armor steel as cover or bottom of the box. At equal other parameters, that enables examining the possibility to use armor steel when introducing light armor for modernization of armor vehicles. The armor plate thickness depends on its specific function in the vehicle.

4. Preparation of silicate-polymer composite

4.1. Recipe:

- Epoxy resin AP-1 - 1 l;
- Ethanol - 0.080 l;
- Water - 0.080 l;
- Polyviol - 0.001 l;
- Hardener - 0.080 - 0.100 l;
- Reactive mineral filler - 0. 240 kg;
- Spheroid granules or tablets - 2.5 l.

The composite quantity is calculated according to the quantity of boxes which are filled

4.2. Preparation

- Keeping the epoxy resin and the boxes at 25 - 30°C;
- Ethanol and water are admixed to the resin with intensive stirring;
- After complete homogenization 10 - 12% hardener is admixed with continuous stirring;

- Reactive filler and metal powder, in case such is provided for are added,
- After homogenizing of the mix gas release begins and the respective volume of granules or tablets is added.

IV. PARAMETERS OF THE LIGHT ARMOR

The light armor is characterized in a comparetively large number of parameters. In view of financial and time limitations of the Contract the parameters examined are reduced to the following:

1. Parameters characterizing the phase content:

1.1. Content of spheroid granules, i.e. presence of a metal powder;

1.2. Content and coating of the ferrous silicate tablets;

1.3. Presence of bronze filings;

1.4. Presence of metal powders.

2. Geometry parameters of the boxes which pack the silicate-polymer composite:

2.1. Height of the box;

2.2. Number of boxes.

3. Type and thickness of the steel plates used for manufacturing both the elements crossing charge jet direction and ribs.

V. METHOD FOR STATIONARY TESTING OF LIGHT ARMOR SPECIMENS USING SHAPED CHARGES

1. General

1.1. The method is related to testing of light armor specimens performed upon the current Contract task.

1.2. The purpose of the testing is to assess the influence of some technological and design parameters of the light armor on its protective capability compared to the protective capability of monolithic armor of moderate hardness.

2. Testing conditions

2.1. The tests are performed in stationary conditions by shaped charges of piercing ability 470mm monolithic armor of moderate hardness at obliquity 60° toward the normal.

2.2. The shaped charges used are produced in conformity with producer's quality certificate.

2.3. The shaped charge is positioned on the tested specimen by means of a positioning device for the particular obliquity and optimum focus distance. After checking the angle of positioning the shaped charge is activated.

2.4. For the purposes of the testing the piercing ability of the shaped charge in a reference monolithic armor is not determined by experiments but an average value of 470mm is accepted which is verified repeatedly. Although on demand of the Assignor's representative attending a check testing is made with 3 shots to a reference armor plate at obliquity 60^0.

2.5. For determining the light armor specimens' protective ability the letter are placed on a witness plate 200mm thick or on a set of two armor plates each of them 100mm thick which are placed one over another without air gap.

2.6. Each specimen is tested by one charge. The distance between the center of the charge jet inlet and the edge of the witness plate should not be less then 100mm.

2.7. There should not be any concrete or metal walls at a distance up to 3m under/behind the target stand downstream the charge jet but earth mass at a distance less then 0.5m.

2.8. The preparation of the shaped charges as well as their positioning and firing is carried out by the personnel of the Proving Ground under commands of the Chief.

3. Assessment of the tested armors

A criterion characterizing the increase of protective effectiveness in comparison to a reference armor is the relative reduction in jet penetration depth L_{rel} determined by the following

equation:

$$L_{rel} = \frac{L_{ref} - L_{total}}{L_{ref}} .100\%,$$

wherein:

L_{ref}= 470mm is the penetration into a reference monolithic steel armor of moderate hardness, mm;

$L_{total} = L_{norm} + L_{witn}$ is the total charge jet penetration into target, mm

wherein:

L_{norm} - is jet penetration into light armor specimen normalized to armor steel, mm and

L_{witn} - is jet penetration into witness plate

4. Performing the test

4.1. The light armor specimens are tested in succession. After each test the depth of jet penetration into specimen and witness plate, provided the specimen is pierced is measured by means of depth measuring rod.

4.2. In case charge piercing ability needs checking three tests of the standard armor are performed. The average value of penetration depth is accepted for L_{ref}.

4.3. The testing results are filled in Table 1 and the impact place on the witness plate is marked. After accomplishing the testing a written statement is made in which all conditions and results obtained are recorded.

5. Safety measures

5.1. During preparation and carrying out the testing all the safety requirements for handling ammunitions are strictly observed in compliance with range testing regulations.

5.2. The personnel should observe all specific requirements for armors testing with shaped charges.

5.3. The personnel and observers are allowed to be present at the place of testing during positioning the charge and checking the angle of positioning. After that only the firing specialist is allowed to stay at the place.

Table

Specimen No	Penetration depth downstream the charge jet, mm								
	In the specimen		In both plates before disconnection*	In the upper plate			In the lower plate*		
	Composite	Steel		Presence of an inlet	Presence of an outlet	Depth	Presence of an inlet	Presence of an outlet	Depth
1									
2									

* - in case the witness consists of two plates.

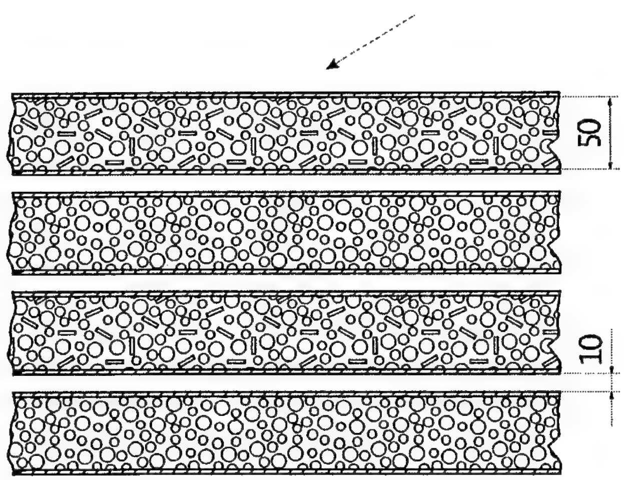
VI. EXPERIMENTAL EXAMINATION OF LIGHT ARMOR SPECIMENS PROTECTIVE EFFECTIVENESS AGAINST SHAPED CHARGES

In accordance with the materials, designs and technologies described seventy armor specimens for testing with shaped charges are developed and manufactured. The specimens are tested in range conditions according to the Method for testing mentioned. The tests are performed in June and October 2000 and in February, March and June 2001.

The results of the testing are given in Tables 1, 2, 3, 4 and 5 respectively. After each table conclusions are given.

1. Light armor testing on June 29, 2000 /470mm, 60^0/

Table 1

Specimen No	Scheme	Composition of the granules	Composite content	Penetration into target downstream the jet, mm normalized to steel: In the specimen, Composite	In the specimen, Steel	In the witness	Total	Protect. effect increase, %
15		Mix 1	With filings	49.9	32	63	144.9	69.2
16		"	"	46.8	"	52	130.8	72.2
17		"	Without filings	22.9	"	99	153.9	67.2
18		"	"	22.9	"	95	149.9	68.1
19		"	2 boxes with filings and 2 without	36.9	"	62	130.9	72.1
20		"	"	35.9	"	114	181.9	61.3

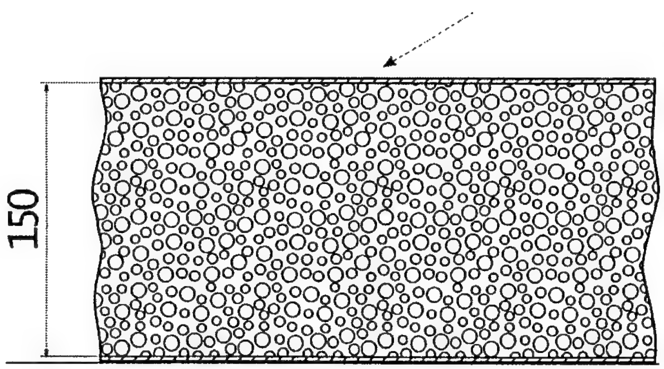
Conclusions

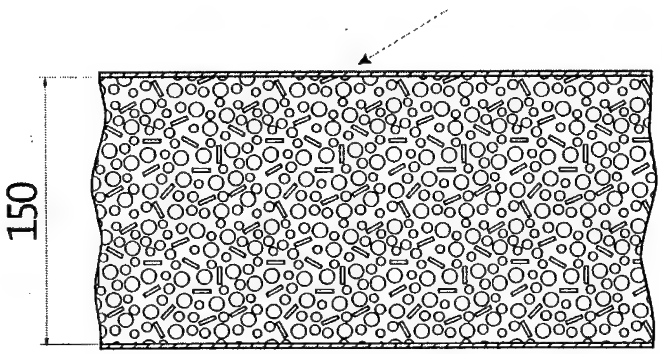
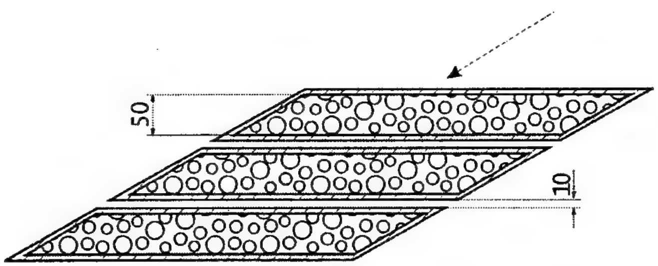
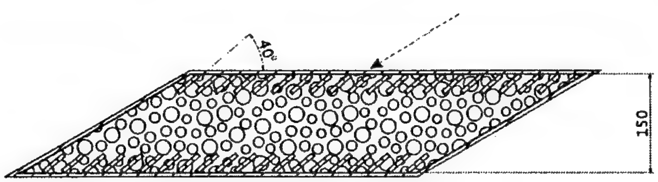
from the testing of June 29, 2000

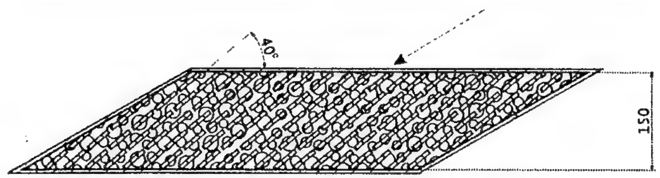
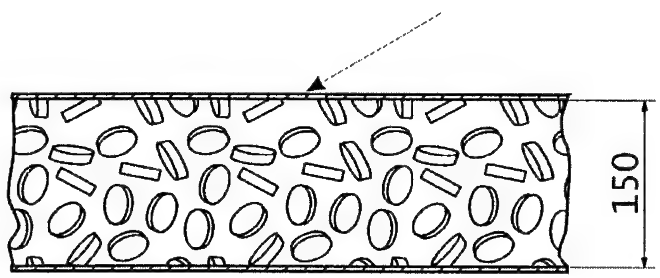
1. In all tested specimens a high protective effect and a relative repeatability of the testing results are observed.
2. The small difference in protective effect when using bronze filings (Specimens No15 and 16) does not confirm undoubtedly their advantage because of insufficient number of tests performed.
3. It is necessary in future testing to examine the influence of geometry parameters, i. e. quantity and height of the boxes.

2. Light armor testing on October 16,2000 /470mm, 60^0/

Table 2

Specimen No	Scheme	Composition of the granules	Composite content	Penetration into target downstream the jet, mm normalized to steel				Protective effect increase %
				In the specimen		In the witness	Total	
				Composite	Steel			
1	2	3	4	5	6	7	8	9
21		Mix 1	Without filings	16.8	4	320	340.8	27.5
22		"	"	16.4	4	355	375.4	20.1
23		Mix 2	"	19.8	4	285	308.8	34.3
28		Mix 3	"	26.8	4	237	267.8	43.0
29		Mix 4	"	21.0	4	320	345.0	26.6
30		Mix 5	"	21.4	4	112	137.4	70.8
31		Equal quantities of 1, 2, 3, 4 and 5	"	21.4	4	262	287.4	38.8

1	2	3	4	5	6	7	8	9
24		Mix 2	With fil-ings	30.2	4	278	312.2	33.6
25		Mix 1	"	27.8	4	293	324.8	30.9
26		"	"	28.2	4	320	352.2	25.1
32		Mix 3	"	37.4	4	250	291.4	38.0
33		Mix4	"	29.4	4	118	151.4	67.8
34		Mix5	"	33.2	4	121	158.2	66.3
35		Mix 1	Without filings	18.0	12	125	155.0	67.0
36		"	"	14.0	65	93	172.0	63.4

1	2	3	4	5	6	7	8	9
37		Mix 1	Without filings	12.0	160	5	177.0	62.3
27		Tablets of Mix10	Without filings	52.0	4	233	289.0	38.5

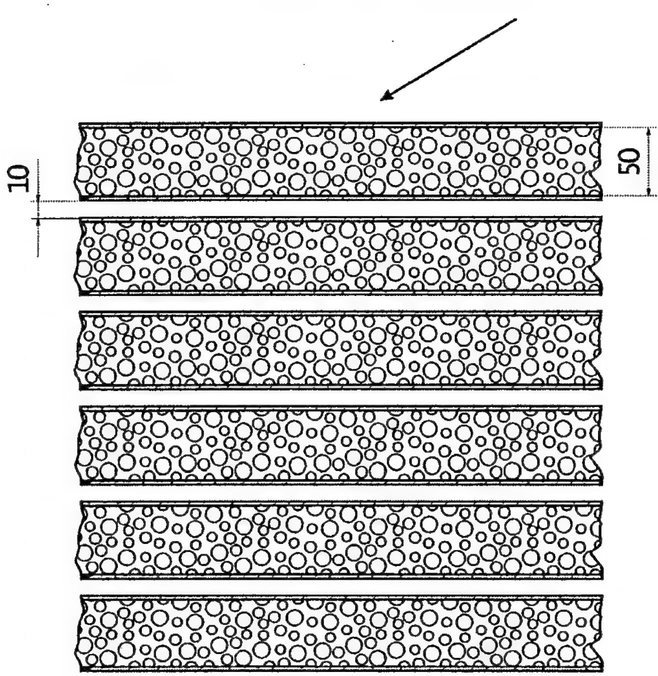
Conclusions

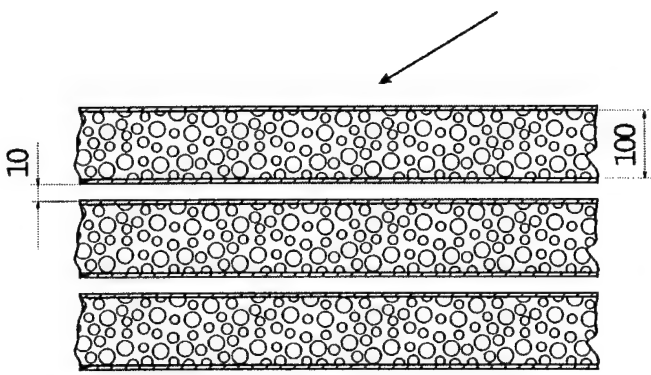
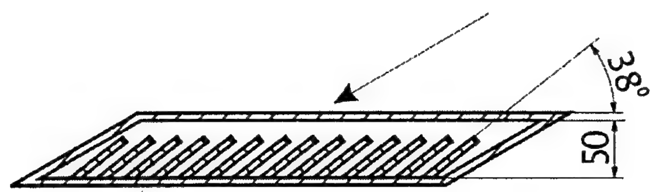
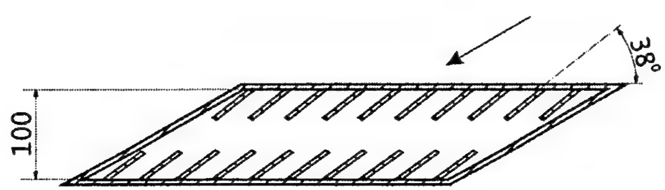
from the testing of October 16, 2000

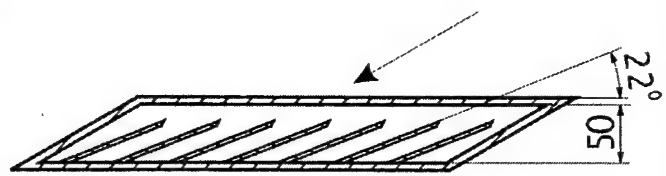
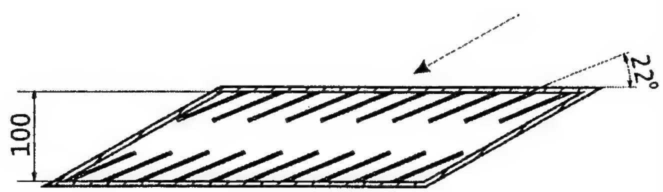
1. The significant dispersion in protective effect values is explained with the variety of materials used as a phase of silicate-polymer composite.
2. Higher results are obtained when using zinc and copper powder in spheroid granules. For a more determined assessment it is necessary to test at least two specimens of equal embodiment and components.
3. The presence of bronze filings in the composite does not lead to a significant protective effect increase which combined with a possible presence of lead and some technological and economic difficulties gives a reason to cease examination in that direction.
4. The lower results obtained at an equal composite content in comparison with the testing from June 2000 may be explained with the presence of a single box 150mm high. Manufacturing of specimens using a bigger quantity of boxes 50 to 100mm high is advisable.

3. Light armor testing from February 12, 2001 /470mm, 60^0/

Table 3

Speci-men No	Scheme	Composi-tion of the granules	Composite content	Penetration into target downstream the jet, mm				Protective effect in-crease, %
				In the specimen		In the wit-ness	Total	
				Composite	Steel			
1	2	3	4	5	6	7	8	9
38		Mix 1	Without filings	39.9	24	82	145.9	69.0
39		"	"	39.9	24	80	143.9	69.4
42		Mix 5	"	42.6	24	59	125.6	73.3
44		Mix 6	"	51.8	24	22	97.8	79.2
46		Mix 3	"	44.4	24	62	130.4	72.2
48		Mix 7	"	63.9	24	26	113.9	75.8
50		Mix 4	"	46.1	24	51	121.1	74.2
52		Mix 8	"	70.6	24	28	122.7	73.9

1	2	3	4	5	6	7	8	9
40		Mix. 1	Without filings	38.7	12	90	140.7	70.1
41		"	"	38.7	12	77	127.7	72.8
43		Mix 5	"	38.3	12	62	112.3	76.1
45		Mix 6	"	49.2	12	125	186.2	60.4
47		Mix 3	"	44.2	12	80	136.2	71.0
49		Mix 7	"	60.5	12	109	181.50	61.4
51		Mix 4	"	41.2	12	90	143.2	69.5
53		Mix 8	"	67.9	12	77	156.9	66.6
54	 6 boxes 300x150x50mm,	Without granules	Zinc powder 0.330kg per box	invalid				
55	 3 boxes 300x150x100mm,	"	Zinc powder 0.660 kg per box	37.4	84.8	47	169.2	64.0

1	2	3	4	5	6	7	8	9
56	 6 boxes 300x150x50mm,	Without granules	Zinc powder 1.660kg per box	74.7	69.3	36	180.0	61.7
57	 3 boxes 300x150x100mm,	"	Zinc powder- 1.660kg per box	38.7	53.5	44	136.2	71.0

Conclusions

from the testing of February 12, 2001

1. Concerning metal powders usage:

1.1. Using a metal powder in the granules is advantageous to a certain extent but is not clearly manifested. Additional tests are necessary for determining the optimal quantity and the type of metal included in the granules.

1.2. All three metal powders used in the granules are equally advantageous.

1.3. Using a bigger quantity of metal powder in the granules is not advisable. The advisable weight percentage ratio of I-20-20 to metal powder is 88:12.

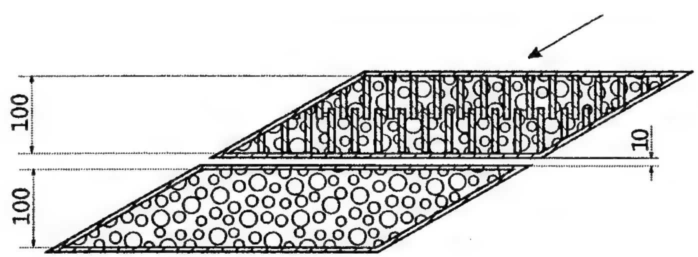
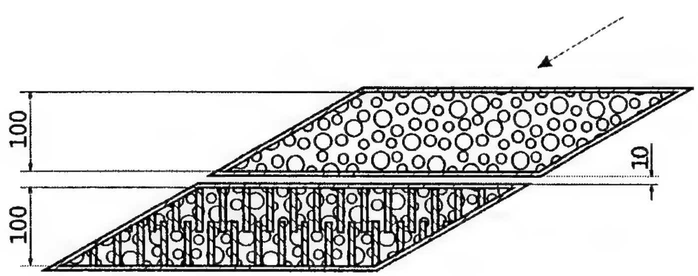
1.4. Before choosing a certain metal powder to be included in the granules some technological and economic factors has to be considered.

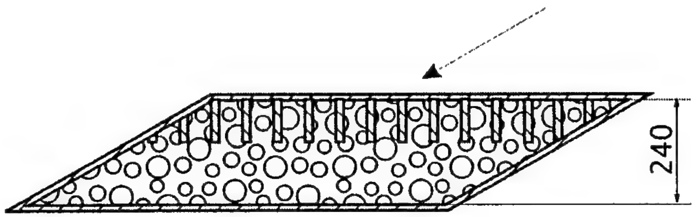
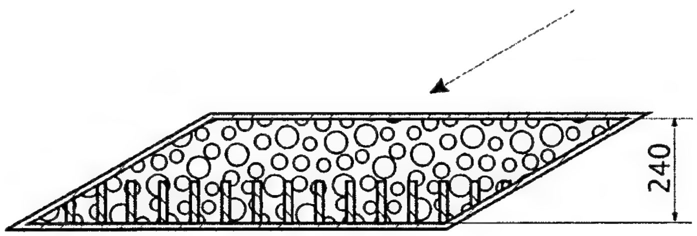
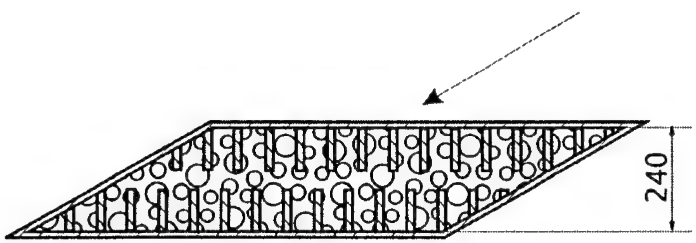
2. Dividing the specimen into six boxes with height 50mm each is more advantageous in comparison with the embodiment with three boxes 100mm each.

3. Specimens No 54, 55, 56 and 57 with ribs and metal powder without granules included in the composite show high protective effectiveness as a whole but yield to the rest specimens in respect both to protective effect and economical characteristics. It is advisable to examine the function of the ribs in various embodiments, including such with granules instead of metal powder as a phase.

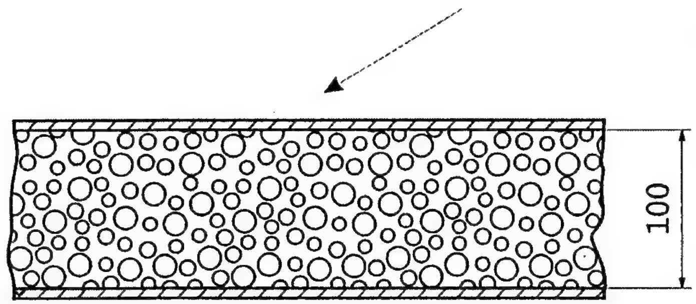
4. Light armor testing on March 30, 2001 /470 mm, 60^0/

Table 4

Speci men No	Scheme	Composi-tion of the granules	Composite content	Penetration into target downstream the jet, mm normalized to steel				Protect. effect increase %
				In the specimen		In the witness	Total	
				Composite	Steel			
1	2	3	4	5	6	7	8	9
58		Mix 9	Without filings	35.5	80	150	265.5	43.5
59		"	"	37.6	80	72	189.6	59.6
64		"	"	36.3	80	85	201.3	57.1
65		"	"	38.3	80	115	233.3	50.4

1	2	3	4	5	6	7	8	9
60		Mix 9	Without filings	33.5	40	190	263.5	43.9
61		"	"	32.7	40	110	182.7	61.1
62		"	"	35.6	40	136	211.6	55.0
63		"	"	33.4	40	56	129.4	72.5
66		"	"	39.3	52	55	146.3	68.9
67		"	"	35.2	52	177	264.2	43.8

Page 3

1	2	3	4	5	6	7	8	9
68		Mix 9	Without filings	18.0	28	167	213.0	54.7
69		"	"	19.7	28	199	246.7	47.5

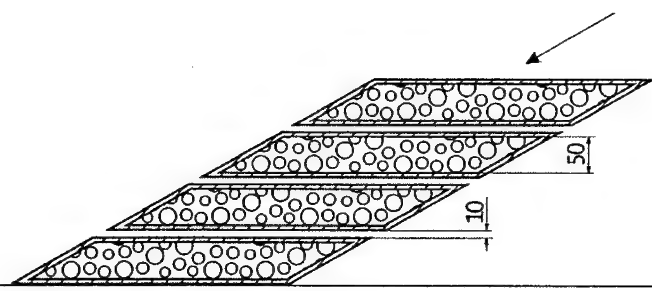
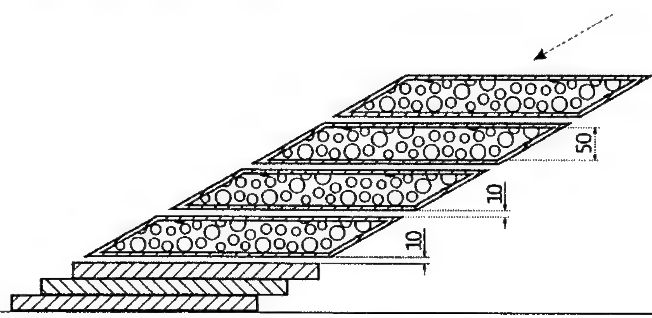
Conclusions

from the testing of March 30, 2001

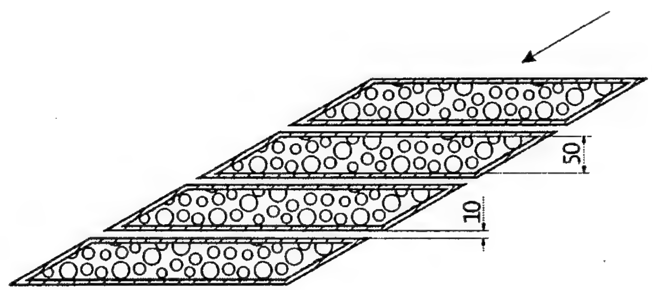
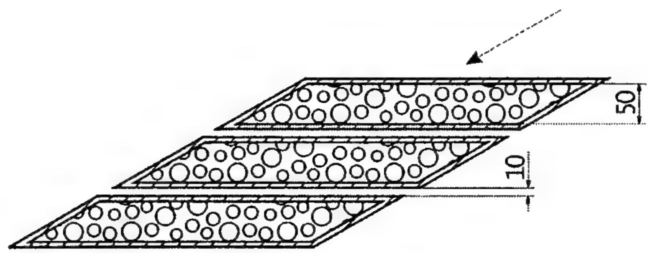
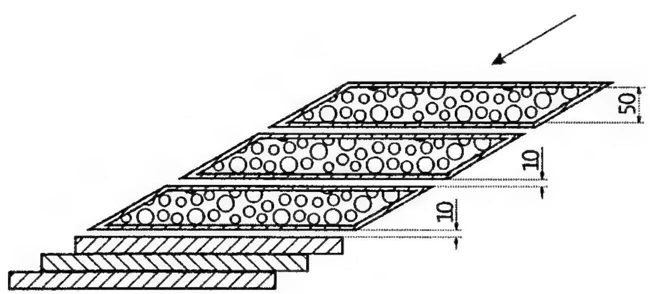
1. Regardless of the good testing results embodiments with ribs do not show any advantages to embodiments without ribs. It may be expected that an embodiment with ribs is more appropriate in point of view of ensuring a complex protection of light armor vehicles both against kinetic and shaped charges.
2. The use of armor steel sheet 7mm thick as cover or bottom plate of the box neither shows great advantages nor decreases protective effect. That is a useful feature from the point of view of the real armor protection.

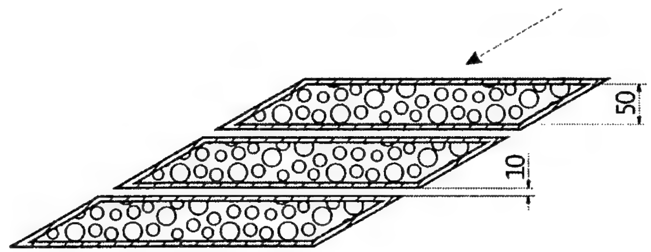
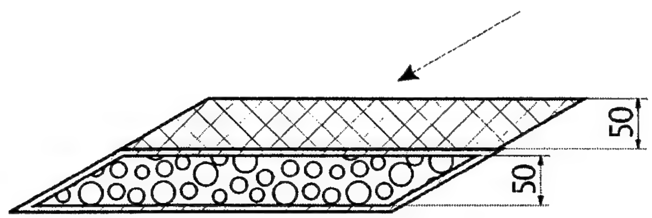
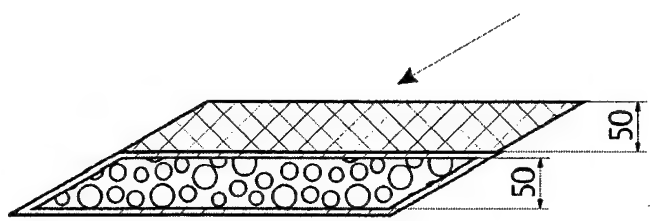
5. Light armor testing at June 5, 2001 / 470 mm, 60^0/

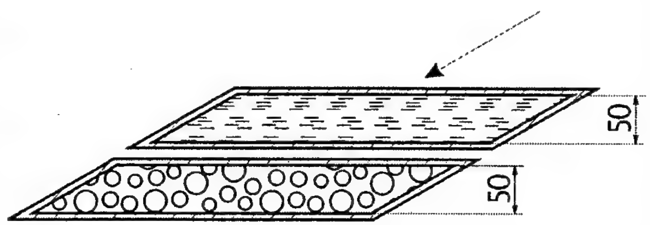
Table 5

Specimen No	Scheme	Composition of the granules	Composite content	Penetration into target downstream the jet, mm normalized to steel				Protective effect increase, %
				In the specimen		In the witness	Total	
				Composite	Steel			
1	2	3	4	5	6	7	8	9
70		Mix 9	Without filings	30.6	112	74	216.6	53.9
71		"	"	30.6	112	25	167.6	64.3
72		"	"	30.6	162	-	192.6	59.0

Page 2

1	2	3	4	5	6	7	8	9
73		Mix 9	Without filings	30.6	12.8	251	294.4	37.4
74			"	30.6	12.8	72	115.4	75.4
75		"	"	22.9	84	190	296.9	36.8
76		"	"	22.9	84	157	263.9	43.8
77		"	"	22.9	210	38	270.9	42.4

1	2	3	4	5	6	7	8	9
78		Mix 9	Without filings	22.9	9.6	133	165.5	64.8
79			"	22.9	9.6	160	192.5	59.0
80		"	"	14.0	28	250	292.0	37.9
81		"	"	14.0	28	56	98.0	79.1
82		"	"	14.0	3.2	255	272.2	42.1
83		"	"	14.0	3.2	115	132.2	71.9

1	2	3	4	5	6	7	8	9
84		Mix 9	Without filings	20.3	19.2	210	249.5	46.9
85		"	"	20.3	19.2	298	337.5	28.2

Conclusions

from the testing of June 5, 2001

1. The results obtained from the testing of Specimens No72 and 77 with armor plate as a bottom element confirm the expectation that designing a light armor capable to prevent completely the jet from penetration is possible.
2. Comparison between Specimens No70-71 and No72 as well as between No75-76 and No77 shows that apart from the above mentioned advantage the use of a thicker armor plate as a bottom element shows no other advantages.
3. The protective effectiveness of specimens consisting of three boxes is higher than that of specimens with four boxes.
4. Changing focal distance as with Specimens No 80, 81, 82 and 83 has proved advantageous for protective effectiveness but the insufficient number of tests does not allow to assess the prospects for a further research in that direction.
5. The testing results from specimens filled with hydraulic solution are lower than that achieved in year 1998 at different characteristics of hydraulic solution used.
6. The dispersion of results in parallel testing, e. g. Specimens No 73 and 74 and Specimens No 80 and 81 is due to the insufficient number of tests and does not allow to assess the results obtained with certainty.

VII. GENERAL CONCLUSIONS

1. The protective effectiveness of specimens consisting of several equal elements with air gaps between them is higher than that of a monolithic block of the same height.
2. Mix 9 is optimal in respect to composition of spheroid granules.
3. Specimens with boxes of thinner sheet steel shows some advantage in point of view of protective effectiveness.
4. Supposedly the main protective function shown by silicate-polymer composite is against the front part of the charge jet, i. e. that of high velocity which needs proving by additional tests.
5. Including metal particles with dimension 1 to 5mm and density equal or higher than that of copper in the phase of silicate-polymer composite leads to increase in protective effectiveness.
6. A significant effect is registered when changing the focal distance at which charge jet forms, so further researches in that direction are advisable.
7. It is advisable to invent a new criterion enabling to give the light armor a more adequate assessment corresponding to the new stage of research.

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